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Oxygen (O^{6+}) ion beam irradiation effects on etching parameter in lexan polymeric track detector

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Abstract : The polymer Lexan was irradiated to 80MeV O^{6+} ion beam using the 15UD pelletron at Inter University Accelerator Centre, New Delhi. The ion fluence ranging from 10^{11} to 3×10^{12} ions/cm^2 has been used to study the dose effects of irradiation on Lexan. By using the etching technique, it is observed that the bulk etch rate of the sample increases with increasing the ion influence, while the activation energy associated with it show a decreasing trend which can be explained on the basis of polymer degradation.

Keywords : Lexan polymer, Oxygen ion beam, bulk etch rate and activation energy of bulk etching

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1. Introduction

Application of irradiation in polymer technology is of great importance in achieving some desired improvement in polymer properties. Ion beam treatment provides a unique way to modify the chemical, structural, optical, mechanical and electrical properties by causing irreversible changes in their macromolecular structure [1-11]. The ion beam irradiation affects the polymer structure by cross- linking as well as by degradation [12]. The present investigations are carried out to analyze the influence of O^{6+} ion beam of energy 80MeV on the etching characteristics of aromatic polycarbonate Lexan. The polymer used during present investigation *i.e.* Lexan poly-carbonate has been procured from General Electrics West Germany having chemical composition and 3D network. The changes in the activation energy for bulk etch rate with ion fluence have also been investigated.

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2. Experimental details

The pieces of Lexan Polymer have been cut from a large sheet of average thickness 85 μm respectively. Some of these pieces were mounted on a vertical vacuum shielded sliding ladder and irradiated to O^{6+} ion of energy 80MeV using the 15UD pelletron facility in the general purpose scattering chamber under high vacuum of 10^{-6} Torr at Inter University Accelerator Center, New Delhi. The irradiation has been made at different fluences ranging from 10^{11} to 3×10^{12} ions/cm^2 for O^{6+} ions. These samples were etched in 6.25N NaOH solution at different temperatures *i.e.* 60ºC, 65ºC, 70ºC, 75ºC, 80ºC (with an accuracy of ± 1^0C) for different time intervals.

To measure the bulk etch rate, we use a direct measurement method *i.e.* thickness measurement method [13] made with a digital micrometer with accuracy of 1 μm. Measurements of V_B with the micrometer are based on the determination of the thickness of the removed layer during etching. To minimize the error, we take measurements at about 25 positions and the average be taken. The bulk rate v_B is measured from the slope of the curve between the thickness and etching time *i.e.* $V_B = T - T'/2t$ where T and T' be the thickness of the sample at a point before and after etching for the time t. The activation energy associated with bulk etch rate at a given temp and at a constant concentration is given as :

$$V_B = \alpha c^n \exp(-E_B/kT) \quad (1)$$

where T is temperature, C is concentration of etchant. For taking the concentration (C) as a constant :

$$V_B = Ac^n \exp(-E_B/kT) \quad (2)$$

Where A is constant and E_B is activation energy for bulk etching, which is a measure of the changes in free energy per molecule between final and initial states.

3. Results and disucssion

The range of 80 MeV O^{6+} ion beams has been calculated using SRIM-2003 and is found to be 88 μm for O^{6+} ions which is greater than the thickness of the polymer. These parameters are chosen in such a way that the modifications will occur only due to the electronic energy loss in the irradiated sample. In the present work, an attempt has been made to analyze the effect of irradiation on the bulk etch rates and the activation energy associated with them due to irradiation. This work is in continuation of our previous work [14] in which we deal with the FTIR and UV-VIS analysis of Lexan polymer irradiated with O^{6+} (80 MeV) ion beam. The bulk etch rates of O^{6+} ion beam irradiated samples of Lexan polycarbonate are summarized in Table 1 and the results reveal that the bulk etch rate increase with fluence of oxygen ion beam.

The dissolution rate of bulk material is affected by the available free energy associated with the creation of damage zones around the ion path. However, in polymers the bulk

Table 1. The variations of the bulk etch rate V_B with fluence of O^{6+} ion beam at different temperatures in case of Lexan plastic track detector.

fluence → (ions/cm^2) ↓ Temp. ($^\circ$C)	For O^{6+} ion beam, V_B (μm/h)				
	0	10^{11}	3×10^{11}	10^{12}	3×10^{12}
60	2.0 ±.1	3.9 ± .1	4.8 ± .3	6.8 ± .6	8.2 ± .8
65	2.2 ± .1	4.9 ± .3	5.4 ± .4	14.6 ± 1.1	15.7 ± 1
70	5.5 ± .2	5.3 ± .3	7.9 ± .9	21.3 ± 1.2	27.0 ± 2
75	5.8 ± .2	10.4 ± .8	11.2 ± 1	25.1 ± 1.4	30.0 ± 2
80	7.8 ± .6	16.5 ± 1	20.1 ± 1	29.6 ± 2.1	31.4 ± 3

etch rate enhancement may be explained by the processes of chain-scission or cross-linking resulting in modification of molecular weight of the irradiated polymer. A similar observation was made by Bhatia *et al* 1990 [15]. They observed the effect of post irradiation oxidation of the samples, increasing the percentage scission of the hydrocarbon chain and hence an increase in the bulk etch rate of CR-39. Generally in plastics, free radicals will be formed from the decomposition of primarily formed hydro peroxides [16]. On comparing our results with UV-VIS spectra analysis of pristine of O^{6+} ion beam irradiated Lexan polymer, the band gap energy is reduced to 3.08 eV from its initial value 4.41eV which may be attributed in case of scission of the polymeric chain and it strengthens our results. The FTIR investigations show similar results and it can be concluded that oxygen has reduced the diffusion rate of π-electrons to the forbidden level for Lexan. The above reason may be ascribed to the oxidative degradation of the polymer, in particular to the formation of alcohols and carboxylic acids [17]. The –OH intensity enhancement is also found to be dominant. The activation energy associated with the bulk etch rate is calculated from the slope of the graph between $10^3/T$ *vs* In V_B as shown in Figure 1 for O^{6+} ion.

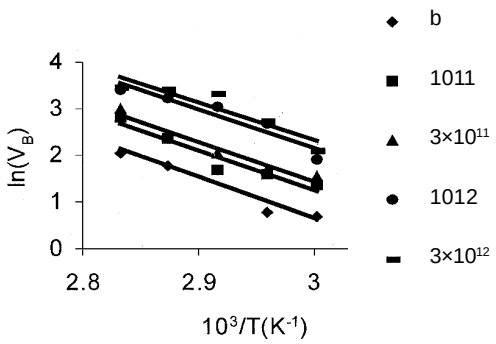

Figure 1. Variation of In (V_B) *vs* $10^3/T$.

The values of activation energies are reported in the Table 2 and it shows a very small decrease with fluence in case of O^{6+} ions.

Table 2. The variations of activation energies for bulk etch with different ion fluences in case of Lexan plastic track detector.

Ion fluence (ions/cm^2)	For O^{6+} ion beam E_B (eV)
0	0.74 ± 0.14
10^{11}	0.73 ± 0.13
3×10^{11}	0.72 ± 0.09
10^{12}	0.71 ± 0.14
3×10^{12}	0.68 ± 0.12

4. Conclusions

On the basis of the above discussion, it can be concluded that with O^{6+} ion beams, bulk etch rates increase with fluence while the activation energy associated with them show a very small decrease. It means the oxygen ion beam irradiation enhances the degradation process of the polymer through bond breakage and formation of free radicals, which may be due to the large size and greater charge on the ion, as it will cause the greater extent of polymer degradation.

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References

[1] P Mazzoldi and G W Arnold *Ion beam modifications of insulators* (Amsterdam : Elsevier) **Vol. 2** (1987)

[2] L Calgagno and G Foti *Nucl. Instrum. Meth.* **B19/20** 895 (1987)

[3] J Davenas, P Thevenard, G Boiteux *Nucl. Instrum. Meth.* **B46** 317 (1990)

[4] E Ferain, R Legras *Nucl. Instrum. Meth.* **B222** 518 (2004)

[5] E H Lee, Y Lee, W C Oliver and L K Mansur *J. Mater. Res.* **8** 229 (1993)

[6] R Ochsner *Nucl. Instrum. Meth.* **B1** 1050 (1993)

[7] M V Swain, A J Porry, J R Trogloo, E D Domaroo *J. Mater. Res.* **12** 1917 (1997)

[8] C Z Wang and K M Ho *Phys. Rev. Lett.* **71** 1184 (1993)

[9] G R Rao, K Monar, E H Lee and J R Treglio *Surf. Coat. Technol.* **64** 69 (1994)

[10] S Schiestel, W Ensinger and G K Wolf *Nucl. Instrum. Meth.* **B91** 473 (1994)

[11] V Vorcik, V Rybka, R Endrst, V Hnatowicz, J K Vitek and P Seidi *J. Appl. Poly. Sci.* **49** 1939 (1993)

[12] E H Lee *Nucl. Inst. Meth.* **B151** 29 (1999)

[13] W Enge, K Grabisch, L Dallmeyer, K P Bartholom and R Beaujean *Nucl. Instrum. Methods* **127** 125 (1975)

[14] S Prasher *Ph.D.Thesis* (2005)

[15] R K Bhatia, R C Singh and H S Virk *Nucl. Instr. Meth.* **B46** 358 (1990)

[16] T Portwood, D L Henshaw and J Stejney *Nucl. Tracks* **12** 109 (1986)

[17] N B Colthup, L H Daly and S E Wiberley *in Infrared and Raman Spectroscopy* (New York : Academic Press) p265 (1990)